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## TRACE METAL POLLUTION STUDIES OF FINFISH AND SEDIMENT FROM THE LAGOS LAGOON

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### ABSTRACT

Concentrations of Cd, Pb, Mn, Zn, and Cr were determined in sediment and finfish samples, collected in December, 2002 (dry season) from the Lagos lagoon and Forcados river, Nigeria. For the sediment samples, levels ranged from undetected to high levels in some locations. For the metals Cd, Pb, Mn, Zn, and Cr the mean concentrations in sediment were,  $5.13 \pm 0.74$ ,  $78.76 \pm 23.23$ ,  $293.9 \pm 198.55$ ,  $50.23 \pm 13.93$ ,  $27.45 \pm 8.55 \mu\text{g g}^{-1}$  respectively, while in the fish samples the mean concentrations were, 0.21,  $1.78 \pm 1.04$ ,  $0.60 \pm 0.24$ ,  $2.62 \pm 0.77 \mu\text{g g}^{-1}$  respectively. Chromium was not detected in any of the fish samples. Pb exceeded the WHO limits in two fish samples. In contrast, all other metals exhibited low concentrations in the fish samples. The monitoring of selected elements in sea food is considered necessary, both to delineate any temporal change in trace metal levels in locally available organisms and to ensure that concentrations Pb does not increase further. In this study the distribution and sources of the metals in sediment and fish from the different locations of the Lagos lagoon and Forcados river are discussed.

**Keywords:** Trace metals, fin fish, sediment, Lagos Lagoon, Forcados River.

### INTRODUCTION

Finfish and shellfish have been widely used as bio-indicators to monitor trace and heavy metal concentrations in the environment due to their wide range of distribution and their important role in the food chain (Nieboar, *et al.*, 1981; Asuquo & Udoh 2002, Asuquo *et al.*, 2003). In principle the same elements are determined in animal and vegetable samples, in foodstuffs etc., as in body fluids and tissue. The principal aspect is healthy nutrition and sufficient supply of minerals and trace elements (Rains, 1991). Trace heavy metals have been identified as important contaminants resulting in undesirable effects in the aquatic environment especially fisheries (Oyewo, 1998).

Another very important aspect of the analysis of biological materials is the intake of heavy metals in concentrations injurious to health from nutrition. The accumulation of metals such as cadmium, lead, and mercury in predatory fish are known examples. Food poisoning resulting from consumption of food contaminated with cadmium came into

dispute first in Japan with the occurrence of 'itai-itai' disease (Posselt, *et al.*, 1971). Acute lead poisoning is nevertheless seldom due to low resorption in tissues (Welz & Sperling, 1999). A striking example of fin/shellfish poisoning caused by consumption of fish contaminated with inorganic mercury resulted in the 'Minimata' disease which occurred in Minamata Bay, a small fishing town in Japan (Craig, 1986). Accumulations of methylmercury in fish and shellfish in different parts of the world have been documented (Bryce-Smith, 1972).

The determination of trace and heavy metals can also serve to identify the authenticity of seafood products since particularities of the environment are always reflected in the products (Robards, *et al.*, 1995).

Studies exist on the state of pollution of Lagos lagoon by heavy metals (Fodeke, 1979, Okoye, 1989, and Ogunsua, *et al.*, 1993). A review of heavy metals in the African environment by Biney *et al.*, (1994) showed that the occurrence and

distribution of heavy metal contaminants were concentrated in urban and industrial areas than unindustrialized areas. Data have been collected on all major environmental matrices (water, sediment, fauna and flora) with emphasis on sediments, confirmed the ultimate sink (90%) for such pollutants (Horowitz, 1991 & Lauder, 1987). In the Lagos lagoon, anthropogenic heavy metal enrichment of Cd, Co, Cu, Cr, Fe, Mn, Ni, Pb and Zn has been reported as emanating from land-based urban and industrial waste sources ((FMAE, 1983, Portman *et al.*, 1989 Ajao *et al.*, 1996).

Pollution studies by Kakulu & Osibanjo, (1988; 1992) also revealed elevated levels of Pb, Cr, Ni, V, and Zn in Port Harcourt and Warri sediments which suggest inputs from petroleum refineries located in the two cities. Okoye, *et al.*, (1991), Kakulu & Osibanjo (1992) reported that the concentration of most trace metals except iron in surface waters and finfish in the Niger delta area and the Lagos Lagoon were generally lower than the global average levels for surface waters and the international drinking water standards.

Ndiokwere & Guin (1983) determined As, Cd, Cr, Hg, Mn, Mo, Ni, Se, and Sb in two Nigerian rivers and two harbors and attributed high metal concentration to local pollution sources. Background levels of heavy metals in unpolluted sediments are now reasonably well established. GESAMP, (1985, 1988) showed that the overall mean content and range of Hg, Cd, and Pb in unpolluted sediment samples are 0.01-0.08, 0.2-5.0, n.d-8.60  $\mu\text{g g}^{-1}$  respectively.

This report however aims at assessing levels of trace heavy metals such as Cd, Pb, Mn, Zn, and Cr in finfish and sediment from the Lagos lagoon and their tissue distribution in three fish species; Threadfin, *Galeoides decadactylus*, Grunter, *Pomadysys jubelini*, and Tilapia, *Tilapia zilli*, from the Lagos lagoon and Forcados river, Nigeria. The paper also compares the metal concentrations in sediments from the different locations.

## MATERIALS AND METHOD

### Study Site

Lagos lagoon, the largest Lagoon in the Gulf of Guinea is located between longitude  $3^{\circ} 23'$  and  $3^{\circ} 40'E$  and Latitude  $6^{\circ} 22'$  and  $6^{\circ} 48'N$ , (Fig.1), receives a number of rivers (Yelwa, Ogun, Ona, and Oshun) draining more than 103,626  $\text{km}^2$  of Nigeria. The Lagos lagoon complex is a highly urbanized brackish ecosystem and is impacted by mainly municipal and industrial activities that have increased significantly with increasing population

density over the past 50 years. Details of the methodology are reported in (FAO fisheries Technical paper No. 212, 1983). The sediment sampling stations are shown as 1 to 5 in Fig. 1. The locations are Oworonshoki (1), Yaba (2), Iddo (3), Ijora (4), Apapa Wharf (5). The choice of sediment sampling stations was influenced by closeness to industrial locations and release of effluents by these industries

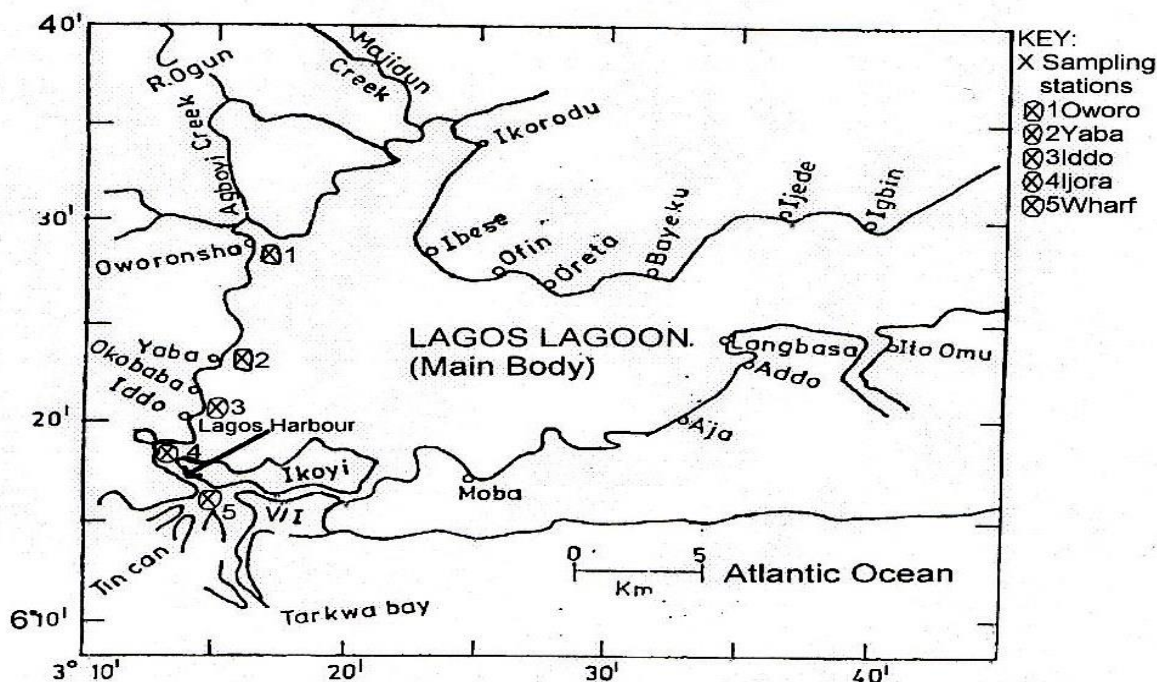
### Collection of Fish Specimens and Preservation

Fish samples were purchased from fishermen at Iddo area (station 3 in Fig.1), the landing sites, before they were taken to the market to avoid contamination. The samples purchased were immediately transferred to a thermo-insulated cooler filled with ice-blocks and taken to the laboratory. In the laboratory the finfish samples were identified, washed with distilled water and immediately preserved in a deep freezer to avoid deterioration.

### Experimental

The preparation of samples prior to actual analysis was carried out in a clean and dust free laboratory. Frozen finfish samples were allowed to thaw in a plastic plate, dissection of the fish was carried out using plastic knives. Muscular tissue for metal analysis was taken from the left side dorsolateral muscle of the finfish samples. Composite samples were also prepared from finfish samples whose muscles were not enough to give 10g sub-sample. About 10g of finfish fresh weight tissue sample was placed in a beaker and 15 ml of freshly prepared mixture of  $\text{HNO}_3/\text{H}_2\text{O}_2$  (1:1, v/v) was added. The beaker was covered with a watch-glass and set aside for about 1 hour, during which the initial reaction would have subsided. The beaker and its contents were placed on a hot plate, whose temperature was allowed to rise gradually, not exceeding  $160^{\circ}\text{C}$  in a fume cupboard. Heating continued for about 2 hours, reducing the volume in the beaker to about 2-5 ml. The beaker and its contents were allowed to cool and transferred with whatman filter into a 25 ml volumetric flask, and made up to mark with distilled water.

Bottom sediments in the study area were collected with the aid of a stainless steel grab of the Van-Veen type. The sediment samples were subjected to low temperature ( $50 \pm 2^{\circ}\text{C}$ ) oven drying for 8-12 hours. After drying visible remains of organisms and debris were removed. The dried samples were crushed in a porcelain mortar and sieved through 63  $\mu\text{m}$  screen. 1 g was placed in a plastic beaker along with 25 ml of 0.5 N HCl. This mixture was stirred for 2½ hrs with a magnetic stirrer instead of a mechanical shaker a modification of a method of Whitehead *et al.*, (1984). This cold extraction method was sufficient to



**Fig.1** Location map of Lagos lagoon showing the sampling stations

release the loosely held fraction into solution. All digests and extracts obtained as described above were filtered through a whatman filter paper and made up to the 50 ml mark in a volumetric flask. Reagent blanks were also prepared accordingly to test the purity of the reagents. Metal concentrations for all extractions were determined by AA Spectrometer Pie Unicam 969, 1996 model.

Accuracy was assessed by analyzing three replicates of selected samples yielding coefficient of variation lower than 10 % for Pb, 5 % for Cd, Zn and Cr. As a check of the suitability and repeatability of the digestion and analytical methods, percentage recovery were calculated for each of the metals-Pb, Cd, Cr, Zn, and Mn in a series of five analyses of fish and sediment samples. This was made by spiking the samples with a known amount of a mixed standard of the metals. The acceptable recovery was set within 79 to 110 % of added amount. The mean recoveries and the standard deviations were as follows; Cr  $98.2 \pm 11.26$ , Pb,  $95.2 \pm 7.12$ , Cd,  $93.20 \pm 5.36$ , Mn,  $83.80 \pm 2.95$ , Zn,  $87.20 \pm 6.18$ . All the results were corrected based on recovery.

## RESULTS AND DISCUSSION.

The total concentration of metals in sediment samples (Table 1) show a wide range of values from undetected to values considered as indicators

of gross contamination. For the metals, Cd, Pb, Mn, Zn, and Cr the mean concentrations in sediment were,  $5.13 \pm 0.74$ ,  $78.76 \pm 23.23$ ,  $293.9 \pm 195.55$ ,  $50.23 \pm 13.93$ , and  $27.45 \pm 8.45 \mu\text{g g}^{-1}$  respectively. The highest Pb level of  $116.95 \mu\text{g g}^{-1}$  was recorded at Apapa Wharf where there is gross contamination resulting from burning of fossil fuel by sea-going vessels. No Pb was detected in sediment around the Iddo end of the Lagos lagoon. Pb concentrations of  $76.0$  and  $55.35 \mu\text{g g}^{-1}$  were recorded at the Yaba and Ijora locations respectively. Cd was detected in only two locations, Iddo and Oworonshoki, however the levels were low  $4.46$  and  $5.65 \mu\text{g g}^{-1}$  respectively. The highest Zn concentration of  $72.45 \mu\text{g g}^{-1}$  was recorded at Ijora location followed closely by Yaba,  $47.90 \mu\text{g g}^{-1}$ , Iddo,  $46.55 \mu\text{g g}^{-1}$  then Oworonshoki,  $34.0 \mu\text{g g}^{-1}$ . The distribution pattern of total metal concentration in the different locations varied considerably (Fig.2). In the Wharf area of Apapa, the sequence in levels was  $\text{Pb} > \text{Mn} > \text{Cr}$ , with values of  $118.95$ ,  $113.45$ ,  $13.90 \mu\text{g g}^{-1}$  respectively. Zn and Cd were not detected in this location. In the remaining four locations Mn was consistently higher than other metals. In Yaba the sequence was  $\text{Mn} > \text{Pb} > \text{Zn} > \text{Cr}$  with concentrations of  $663.40$ ,  $76.0$ ,  $47.9$ ,  $33.80 \mu\text{g g}^{-1}$  respectively. Cd was not detected in this location. The trend in Ijora differed from the trends in the two locations previously discussed. Here the

sequence was Mn>Zn>Pb>Cr> with concentrations of 148.50, 72.45, 55.35, 36.95  $\mu\text{g g}^{-1}$  respectively. Cd was also not detected in this location. In Iddo location Pb was not detected while Cd was found at low level. The sequence was, Mn>Zn>Cr>Cd with concentrations of 240.70, 46.55, 31.25, 4.60  $\mu\text{g g}^{-1}$  respectively. All the metals were detected in Oworonshoki, and they followed the sequence Mn>Pb>Zn>Cr >Cd corresponding to 303.45, 66.75, 34.0, 21.35, and 5.65  $\mu\text{g g}^{-1}$  respectively. The concentrations and range of Cr, Pb, Cd, Mn, and Zn in finfish, purchased from local fishermen

around Iddo, Lagos lagoon and Forcados river are shown in Tables 2 above. The total concentration of metals in finfish samples (Table 2), show a wide range of values from undetected to values considered to reflect gross contamination. For the metals, Cd, Pb, Mn, Zn, and Cr the ranges in finfish were, n.d to 0.21, n.d to 2.67, 0.44 to 0.98, 1.66 to 3.83  $\mu\text{g g}^{-1}$  respectively. Cr was not detected in any of the fish samples analyzed. High Pb concentration of 2.67  $\mu\text{g g}^{-1}$  wet weight in *Tilapia zilli* sampled from the Iddo end of the Lagos lagoon

**Table 1.** Metal concentration in  $\mu\text{g/g}$  in Sediment from different locations in the Lagos lagoon.

Location	Concentration of Metals in $\mu\text{g/g}$ in Sediment dry weight				
	Pb	Cd	Zn	Cr	Mn
Wharf	116.95	n.d	n.d	13.90	113.45
Yaba	76.0	n.d	47.90	33.80	663.40
Ijora	55.35	n.d	72.45	36.95	148.50
Iddo	n.d	4.60	46.55	31.25	240.70
Oworonshoki	66.75	5.65	34.0	21.35	303.45
Mean	78.76	5.13	50.23	27.45	293.90
STD	23.23	0.74	13.93	8.55	196.55
Range	n.d-116.95	n.d-5.65	n.d-72.45	13.90-36.95	113.45-663.40

**Table 2.** Metal concentration in  $\mu\text{g/g}$  in Fish from the Lagos lagoon (Iddo Area), and Forcados River.

Location	Fish Name	Concentration of Metals in $\mu\text{g/g}$ in Fish fresh wt.				
		Pb	Cd	Zn	Cr	Mn
Forcados River	Grunter	n.d	n.d	2.43	n.d	0.46
	Thread fin	2.36	n.d	2.20	n.d	0.24
Lagos Lagoon	Grunter 3	0.32	n.d	3.46	n.d	0.74
		n.d	n.d	2.12	n.d	0.73
		n.d	0.21	1.66	n.d	0.98
	Tilapia	2.67	n.d	3.83	n.d	0.44
	Mean	1.78	0.21	2.62	-	0.60
	STD	1.04	-	0.77	-	0.24
Range		n.d-2.67	n.d-0.21	1.66-3.83	n.d	0.44-0.98

**Table 3.** Comparison of mean metal concentrations in Nigerian marine environment with other African and accepted International values (compiled from Biney et al; 1994).

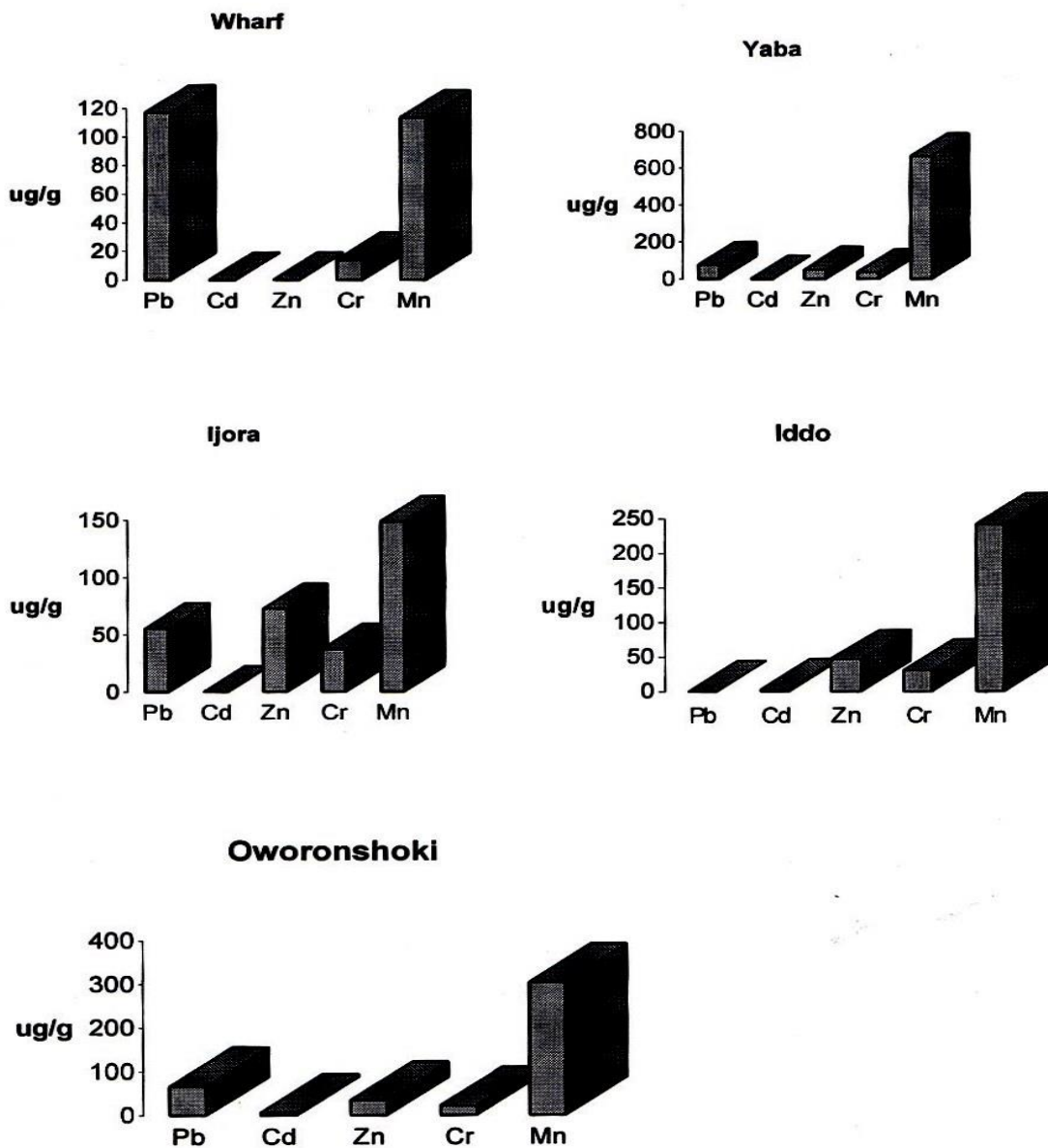
Location	Cd	Pb	Cu	Fe	Zn	Mn	Reference
Lagos lagoon sediment ( $\mu\text{g/g}$ dry wt)	4.10	178.90	-	-	147.0	-	Okoye, 1991a
Atlantic coast sediment ( $\mu\text{g/g}$ dry wt)	2.30	67.5	-	-	72.5	-	Ndiokwere, 1984
West & Central Africa Sediment ( $\mu\text{g/g}$ dry wt)	2.30-4.10	57.6-67.5	-	-	73.0-187.0	-	Biney, et al; 1994
Unpolluted Sediments	0.20-5.0	n.d- 8.60	-	-	-	-	Gesamp, 1985; 1988
Lagos lagoon fin fish ( $\mu\text{g/g}$ w wt)	<0.10	2.28	-	-	27.5	-	Okoye, 1991
African coastal waters Fish ( $\mu\text{g/g}$ w wt)	n.d-0.26	0.07-1.83	-	-	4.23-5.55	-	Biney, et al; 1994
West & Central Africa Fish ( $\mu\text{g/g}$ w wt)	0.03-0.19	0.43-0.48	-	-	7.40-8.0	8.90	Biney, et al; 1994
Cross river estuary fish ( $\mu\text{g/g}$ w wt)	0.18-0.8	3.0-10	0.18-3.0	91.5-243.0	11.3-63.1	0.5-53	Asuquo et al, 2003
WHO limits ( $\mu\text{g/g}$ w wt)	2.0	2.0	-	-	1000	-	Kakulu et al; 1987

and  $2.36 \mu\text{g g}^{-1}$  Pb accumulated by Thread fin *Galeoides decadactylus* sampled from Forcados river, exceeded the WHO (1972) acceptable level of  $2.0 \mu\text{g g}^{-1}$ . The levels of the other metals in the fish samples were very low when compared with the WHO accepted levels.

The pattern of Cd enrichment exhibited by finfish in the present study is consistent with data from river Forcados. (Biney, 1994) and globally (NOAA, 1975). Finfishes are known to contain moderate amounts of this element. The results obtained in this study were also consistent with previous results in finfish from the Lagos lagoon. (Okoye, 1994). Okoye (1984) recorded, Cd,  $< 0.10 \mu\text{g g}^{-1}$ , Pb,  $2.28 \mu\text{g g}^{-1}$ , wet weight concentration in fish. Only the concentrations of Zn, gave marked value of  $27.50 \mu\text{g g}^{-1}$  which was about ten times the highest Zn concentration recorded in this study. The concentration of metals recorded by Biney, et al., (1994) in African coastal fish samples when compared with the present study were markedly lower for Pb,  $0.69 \mu\text{g g}^{-1}$ , close for Zn,

$4.76$ , and Cd  $0.069 \mu\text{g g}^{-1}$  and higher for Mn,  $8.90 \mu\text{g g}^{-1}$ .

Considering the WHO limits of  $2.0 \mu\text{g/g}$  wet weight for Pb, it is very obvious that the tolerable limits of WHO were exceeded in 33% of the fin fish samples analysed and is a source of concern. The incremental addition of lead to seafoods, from urban dust and from aerosols (from automobile exhausts) is likely responsible for this high levels. High levels of Pb have been reported in previous studies in the Nigerian coastal waters and other parts of Africa. Kakulu et al., (1992) reported Pb levels of range n.d- $6.40 \mu\text{g g}^{-1}$  fresh weight in finfish from Warri area which exceeded WHO standards in some samples. In Kenya high Pb levels of range  $1.22$ - $6.48 \mu\text{g g}^{-1}$  fresh weight have been reported.



**Figure 2. Levels of Heavy Metals in Sediment at different locations.**

This high levels of Pb in the Finfish from the Lagos lagoon and Forcados river makes its regular monitoring very necessary. Finfish regulate the concentration of Zn in muscle tissue (Philip, 1977). This is likely to be responsible for the almost uniform concentration of this element in fin fish samples from the Lagos lagoon and Forcados river. The observed Zn concentration range of 1.66-3.83  $\mu\text{g g}^{-1}$  fresh weight in this study are by no means exceptional and are unlikely to present any health hazard. Cr was not detected in finfish studied. Chromium is currently banned in sea food in developed

countries, although the present results does not suggest that problem exists concerning public health and this element deserves continuous monitoring. The carcinogenicity of hexavalent Cr to man and other mammals and the prevalence of the use of this metal in the leather and textile industries, provides sufficient motivation for the continued monitoring for local seafood for this metal. The concentrations of heavy metals in the Lagos lagoon sediments are consistent with previous studies in the lagoon and other parts of Africa (Table 3). Okoye *et al.*, (1991) showed that sediment from highly impacted area of the Lagos lagoon contained Cd, 4.10  $\mu\text{g g}^{-1}$ , Pb, 178.9

$\mu\text{g g}^{-1}$  and Zn,  $147.0 \mu\text{g g}^{-1}$ . The levels of heavy metals in Atlantic coast sediments reported by Ndiokwere *et. al* (1984) are as follows Cd,  $2.30 \mu\text{g g}^{-1}$ , Pb,  $67.5 \mu\text{g g}^{-1}$ , Zn,  $72.5 \mu\text{g g}^{-1}$ . The results of the work on West and Central African sediments, Biney *et. al.*, (1994) are also consistent with the present study giving the metal concentrations as Cd,  $2.30\text{-}4.10 \mu\text{g g}^{-1}$ , Pb,  $57.6\text{-}67.5 \mu\text{g g}^{-1}$ , and Zn,  $73.0\text{-}187 \mu\text{g g}^{-1}$ .

## CONCLUSIONS

The present study have indicated one major area of concern. Thus Pb levels in finfish have been found to be moderately elevated in 33 % of the fish samples analyzed. The extremely long half-life of this element in humans gives rise to its accumulation in vital organs, such as the liver through out the life of man. This elevated concentration of Pb in finfish from the Lagos lagoon should be viewed with some concern, and further monitoring should be envisaged as a necessary prerequisite, if public health is to be adequately protected. By contrast to the situation with respect to lead, all other metals exhibit no discernible elevated concentrations e.g. (cadmium, Chromium). Zinc is not considered to be of sufficient toxicity to mammals to present problems at their currently observed concentrations.

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## REFERENCES

- Ajao, E. A., Oyewo, E. O., & Unyimadu, J. P; 1996. A review of the pollution of coastal waters in Nigeria. *NIOMR Tech. Paper*. No 107 1-12 pp.
- Asuquo, F.E., EwaOboho, Ita, Asuquo, E.F., & Udo, Paul J (2003). Fish species used as biomarkers for Heavy metal and Hydrocarbon contamination for Cross river, Nigeria. *The Environmentalist* (in press).
- Asuquo, F.E. & Udoh, J.P. (2002) . Patterns of total hydrocarbons , Cu and Fe in some fish from the Cross river estuary, Nigeria. *West African J. Applied Ecology*, 3, 91 - 97
- Biney, C., Amuzu, T. A., Calamari, D., Kaba, N., Mbome, I. L., Naeve, H., Ochumba, P. B.Osibanjo, O., Radeconde, V., & Saad, M.A.H; 1994. Review of heavy metals, ed. Calami David & Heiner Naeve 33-60 *CIFA technical paper No 25*. FAO; Rome., 34-56
- Bryce-Smith, D; 1972. Behavioral effects of lead and other heavy metals. *Pollution 43* , Chemistry in Britain 8, 240-252.
- Craig, P.J. (Eds); 1986. Organometallic compounds in the environment, Longman Group, Harlow, Essex, 65-110 pp
- Fodeke, V.A.A; 1979. Study on heavy metals and microbial contamination of Tilapia specie, in Lagos lagoon. M.Sc Thesis. University of Lagos, Lagos. 112pp
- FAO/WHO; 1972. Report of the Joint Expert Committee on Food Additives. *WHO. Tech. Rep. Ser.*, No 505, 66-72
- FAO/SIDA; 1983. Manual of methods in Aquatic Environmental Research. Part 9 – Analyses of metals and organochlorines in fish. Fisheries Technical paper, FAO, Rome, No 212, 234-246 pp.
- FMHE; 1983. Industrial Waste Management. Monograph Series 1. Greengate Ltd\Federal Ministry of Housing and Environment, Lagos, 75 pp
- GESAMP; 1985. IMO/FAO/UNESCO/WMO/WHO /IAEA/UN\UNEP) Joint Group of Experts on the Scientific Aspects of Marine Pollution, Review of potentially harmful substances-Cadmium, Lead, and Tin Rep. Stud., GESAMP. 22, 116pp.
- Horowitz, A.J; 1991. A primer on sediment trace element chemistry, Lewis, MI, 23-40
- Kakulu, S . E. & Osibanjo, O; 1988. Trace heavy metal pollution studies in sediment in the Niger Delta area of Nigeria. *Environ. Pollut.* , 11, 315-322.
- Kakulu, S . E. & Osibanjo, O; 1992. Pollution Studies of Nigerian Rivers: Trace metal levels of surface waters in the Niger Delta Area. *Int. J. Environ. Stud.* 41, 287-292.
- Lauder, L. (Eds); 1987. Speciation of metals in water, sediment, and soil systems, Springer Berlin, 123 pp
- Nieboar, E., & Richardson, D.H.S. (Eds); 1981. Atmospheric pollution in natural waters, Ann Arbor science publisher, Ann Arbor, 339-388 .
- NOAA; 1975. (National Oceanic and Atmospheric Administration). First Interim report on micro constituent resource survey. Maryland, National Marine Fisheries Service, 34-60 pp
- Ndiokwere, C. L., & Guinn, V. P; 1988. Determination of some toxic trace metals in Nigerian River and Harbor water samples by neutron activation analysis. *J. Radioanal. Chem.* 79, 147-151.
- Ogunsua, A.O., Adebona, M.B., Ako-Nai, K.O., Oluwole, A.F., Ruck, W. & Oyewo, E.O. (Eds); 1993. Metals in the Lagos lagoon, In: Proceedings; International conference on



- heavy metals in the environment, Toronto Canada, 165-168
- Okoye, B. C. O; 1989. A study of some heavy metals in Lagos lagoon. Ph.D theses. Obafemi Awolowo University, Ile-Ife, Nigeria. 300pp.
- Okoye, B. C. O; 1991. Heavy metals and organisms in the Lagos Lagoon. *Int. J. Environ. Stud.* 37, 285-292.
- Oyewo, E.O; 1998. Industrial sources and distribution of heavy metals in Lagos lagoon and their biological effects on estuarine animals. Ph.D Theses. University of Lagos. 250pp.
- Philips, D. J. H; 1977. The use of biological indicator organisms to monitor trace metal pollution in marine and estuarine environments – A review. *Environ. Pollut* 13, 281-317.
- Portman, J.E., Biney, C., Ibe, A.C., & Zabi, S. (1989). State of the marine environment in the West and Central African Region. UNEP Regional Seas Report and Studies No 108-UNEP, 230-245
- Posselt, H.S., & Weber, H.S 1971 Technical Report T 71, University of Michigan Ann Arbor, 158-168 .
- Rains, T.C. (Ed.) 1991. Atomic Absorption Spectrometry -theory, design, and application, Elsevier, Amsterdam-Oxford, 199-226 .
- Welz, B., Sperling, M; 1999. Atomic Absorption Spectrometry, third completely revised edition, Wiley VCH Weinheim, 492-516.
- Whitehead, N.E, Oregoni, B. & Fukai, R; 1984. Background levels of trace metals in Mediterranean sediments. *Villes Journées Etuol Pollutions Lucerne C.I.E.S.M*, pp 233-240